Tools of Electronic Communication and Evaluation of Personalized Medical Education in Adaptive Educational Environment

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Abstract—Medical education is by its nature a complicated educational process that requires not only the transfer of a huge amount of scientific knowledge but also the creation of appropriate conditions in order that students can develop the associated clinical skills. Respectively, the evaluation –as a part of the educational- process is a complicated matter that should take into account the growing increased curricular requirements as well as the students' individuality. This study aims to stress the potentiality of facilitating students' evaluation through Adaptive Educational Systems by proposing such one with an emphasis on its pedagogic model. As it is proposed an instructor can create tests to track the students' learning progress and specify the associated rules. Its content can be adapted to the personalized learning characteristics of medical students while supporting them to realize their cognitive strengths and weaknesses. This characteristic transforms it into a valuable tool for self-directed learning models that fit to the adult students of medical education and make them responsible for their own learning progress.

Keywords—Adaptive Educational Systems, Electronic Communication, Web-based Applications, Evaluation, Higher Education, Medical Education.

I. Introduction

THE fast changing, complex and ever increasing demands on the healthcare delivery system, including the changing patterns of various diseases, require a major shift in medical education. Nowadays the curricular requirements of medical education are much more complex and increased than those of previous decades. Among the priorities of world curricula belong the acquisition of medical knowledge, the patient care, interpersonal and communication skills, medical informatics, ethical principles, and professionalism. The degree of fulfillment of these curricular requirements determines how much competent and skilled the physicians of tomorrow will be. However, every medical student has their own learning characteristics, preferences, interests and rates that should be taken into account in a course design and development of Higher Education. To attain it we –as instructors- need an evaluation process that can be adaptable to the learners' individuality while identifying their cognitive strengths and support them to extend it with reference to the learning objectives of every course.

This is merely potential through Adaptive Educational Systems [2; 3]. These environments aim at individualizing support to students and providing them with the possibility of actively participating in the educational procedure. By the assistance of these systems a student can enter a course according to the knowledge level he acquires. It can be certified by the associated adaptive web-based systems for evaluation that have already been developed by other researchers as it is referred in the next section. Nevertheless, an instructor of medical studies (with all that complexity as it was described above) needs to create tests by themselves and specify the associated rules in order to enhance their role as facilitators of individual learning rate. This is sometimes necessary in order to serve the students' needs of self-evaluation for cognitive purposes.

In the present study we will firstly attempt an overview of related work. Then we will describe the users' demands, the architectural structure and the final form of the development of an Adaptive Educational Environment for Evaluation purposes in Medical Education. The last section regards the special attributes and the innovations of an environment designed for the needs of Medical Education. Our study is completed with the drawn conclusions and our proposal for future work.

II. Related Work

The majority of adaptive educational systems specialized in the facilitation of the evaluation process of the educational practice are based on Computer Adaptive Testing (CAT) technique [9]. A CAT is a test administered by a computer, where the selection of the next question to ask and the decision to stop the test are performed dynamically based on a student profile which is created and updated during the interaction with the system.

In those systems the selection of questions is automatic due to the Item Response Theory (IRT) [6]. IRT, based on strong

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hypotheses, tries to give probabilistic foundations to the non-observable trait measurement problem. Its name is due to considering the items as the basic units of the test, in contrast to Classical Test Theory that is based on norm-referenced testing. That is, the instructors enrich a data base with questions of differential levels and then the system selects the sequence of the questions, which is dynamically adapted to the answers of learners. This is considered as an objective testing to evaluate learners' knowledge as CAT relies on statistical measures to modify the order in which the test items are presented. The combination of CAT with IRT face a major problem: that is multi variables can not be evaluated at a time but they should be separated into parts of a curriculum [1].

Three are the most common problems of the tools that are based on CAT technique: Firstly, several questions are overexposed, while a significant part of the questions remain unutilized [7]. Secondly, the learner has not completely the control of the creation of the diagnostic tests. Such an example is the Athena QTI, which is based on the use of the QTI standard. Thirdly, they do not take into account the specific learning characteristics, needs, preferences etc. The latter is recorded in SIETTE [4] and JellyFish [8] adaptive strategy where are both used to ask short graphical questions in a variety of subjects no matter of the learners' interests but only of their learning needs. SIETTE can be used either for academic grading or for self-assessment purposes. It mimics the teacher behavior when assesses orally a student.

However, as it is observed by its creators, the development and maintenance of the question database is a lengthy procedure because the selection techniques must have a significantly large set of questions available [5].

III. INTRODUCTIONDESCRIPTION OF THE PROPOSED ADAPTIVE ENVIRONMENT FOR EVALUATION PURPOSES

The architectural structure of our proposal that is described in this section is depicted in figure 1. It is mainly characterized by its flexibility and the potentiality of its expansion and applicability in various subjects. The proposed adaptive environment for evaluation purpose is characterized by three subsystems each of which implements one of the three basic components (namely the domain model, the learner model and the pedagogic model). These three models are necessary to every adaptive educational system.

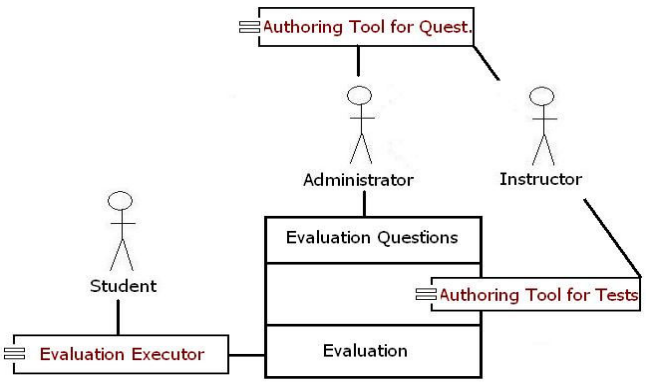

Figure 1. The architectural structure of our proposal the evaluation process

Every subsystem requires different tools to support each model. There are four tools that are needed and which are illustrated in the following figure (figure 2). Detailed description is given in the following paragraphs.

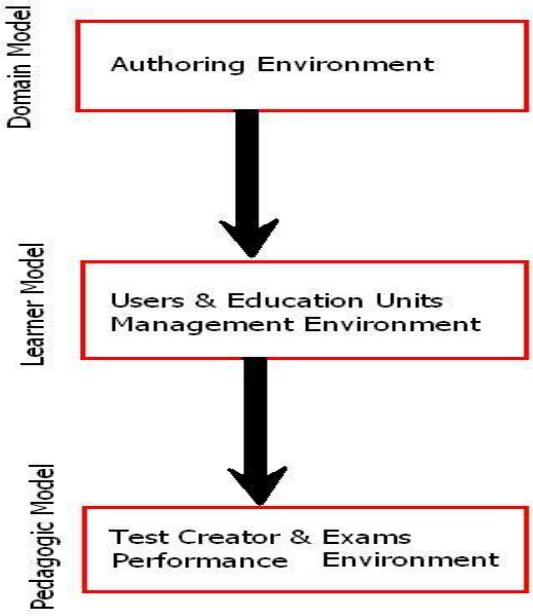

Figure 2. Subsystems and associated tools

The *domain model* concerns that authoring tool that permits the medical instructors to create various forms of questions (e.g. multiple choice questions, true/false questions, open-ended questions, images hot-spot etc.). All these questions are transformed into a XML format and are checked for their conformation with the IMS Question and Test Interoperability (QTI) specification. They can be stored in the system either totally or separately. Also, they can be extracted in XML format in order to be reused by any other application which is conformed to the IMS QTI specification. Simultaneously, the instructor can exploit questions from other resources that are conformed to the IMS QTI specification to introduce them into the system. Using the same XSD of IMS (misqti_v2p0.xsd) the format is checked for its compliance to the rules of the system and then is stored after user's approval. Every question is matched with specific learning goals and subjects. The instructor can form a hierarchy of concepts which are matched with specific questions.

The *learner model* concerns the management of students' profile according to their learning needs, interests, preferences and of course learning goals. The students' data can be extracted in XML format (figure 3), compliant with the IMS Learner Information Package (LIP). The students' information may include their personal data, contact info, demographic data, learning goals, learning preferences, cognitive level, and usage data (namely, the number, duration, quality and result of their efforts). All these information can be updated after the grading of a test.

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<name>
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        <tysource sourcetype="imsdefault" />
        <tyvalue>Preferred</tyvalue>
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            <indexid>name_01</indexid>
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        <typename>
            <tysource sourcetype="imsdefault" />
            <tyvalue>First</tyvalue>
        </typename>
        <text>Athina</text>
    </partname>
    <partname>
        <typename>
            <tysource sourcetype="imsdefault" />
            <tyvalue>Last</tyvalue>
        </typename>
        <text>Lazakidou</text>
    </partname>
</name>
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Figure 3. Learner's first and last name

The *pedagogic model* concerns the tests creation and the rules specification. Specifically, the instructor can specify the grading rules, the minimum and maximum score, the presentation of questions, the learning goals and the additional learning material that may support students during the tests. Also, the test duration may be defined. The grading rules concern the possibility of instructor's clarification of the nature of test namely, if it is designed either for self-evaluation or for official purposes. If the test is designed for self-evaluation purposes, it will be performed whenever and for that number of times that the student determines. The participated students will be defined by the instructor.

Moreover, the students' grading will result from the comparison of the students' answer with the instructor's predefined answer. The instructor may set a default grade e.g. -1 in order that when a student does not answer the corresponding question then one degree will be removed from the student's total score. The total score is a variable defined by the instructor, too. It may be formed either by the total number of questions or by the partial number of some questions. The latter refers to the tree diagram that a set of questions can take in order that the test is performed in parts (figure 4).

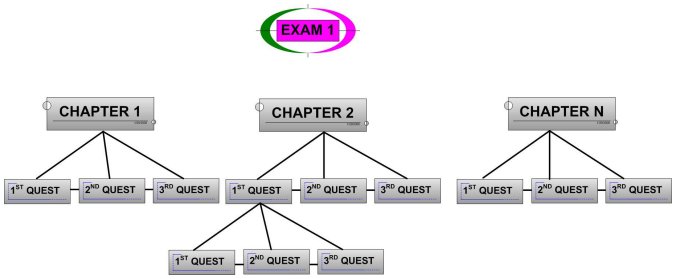

Figure 4. The tree diagram of a test

Every leaf in the tree diagram represents either a different chapter of a subject or a different level of difficulty. The tree diagram also serves the needs of instructor's defining the sequence of questions for each student. As a consequence the phenomenon of cheating can be significantly restricted. Respectively, the pedagogic model can be characterized by flexibility in the issue of test performance. The test can be performed hierarchically with the sequential presentation of questions or in the order that the instructor defines. Also, the instructor can define if a student has the potentiality of returning to a question or not answering one. A question may be connected with a learning goal and as a result the answer of that question defines if a learning goal is attained or not.

Nevertheless, the instructor may define if a student has additional support in a question. For example, specific medical material may be disposed to support students in answering some of the questions of a test.

A. Implementation Tools

The basic structural elements of the proposed environment consist of the following tools:

Tools for Writing Questions

This tool gives the opportunity of editing, modifying or deleting questions. Questions are introduced either through wizards, according to the kind of question, which the creator selects, or through the introduction of questions from XML archives compatible to the IMS QTI standard. The tools for introducing questions into the system belong to the pedagogic model.

Tools for Creating Exams

This tool gives the opportunity to the instructor to create evaluation tests using questions already administered in the system. The instructor can define adaptive rules on the test they create based on the pedagogical perspectives of the specification IMS Simple Sequencing. Thus, the instructor can set: a) grading rules, b) presentation for of the questions, c) specific learning objectives and d) additional educational material. Every test has the form of a tree, which consists only by leaves or by more than one branch, formulating a unit or a difficulty level. In both cases the instructor is that person who specifies the adaptive rules that specify the test form.

Tools for Performing Exams

This tool gives the students the possibility to participate in set exams. The tool adapts the presentation of test according to their preferences, interests and needs. The exams take place the moment that is specified by the instructor. The results of exams are presented to the students and stored in the system updating their profile. The tool for performing exams belongs to the pedagogic model.

Education Units Management Tool

This tool allows the administrator to register the educational units and the students in the system. Then the instructors introduce and manage the students' profile. Moreover, the learning objectives of the student and their allowed interaction with the system are stored. The student model follows the IMS LIP (Learner Information Package) specification and allows

the extract of student facts in XML archives compatible with the above mentioned specification.

B. System Users

The users of the system are divided into three categories:

- Creator (instructor)
- Student
- Administrator.

A creator is defined as that user who takes the decision on issues of evaluation such as the content, the grading rules specification, the performance etc. A student is defined as that user who participates in a learning process of medical subjects and the exams process. Alternatively, a student is that user who intends to test them in an evaluation process (self-evaluation). An administrator is defined that user who is authorized to manage the environment of evaluation. He is permitted to return the tests to creators if they are not completely compliant with specific and specified rules.

C. Technical Characteristics

The technologies of the described system that can be exploited are:

- Microsoft.NET (this is chosen due to its potentiality for providing channels of communication through XML messages)
- XML (it serves the purpose of compliance with IMS standards and of needs for interoperability with other applications)
- Macromedia Flash MX (this is necessary for the performance of questions of images hot –spot)
- SQL Server (for the data storage, retrieval and processing-also, compatible with .NET framework and it supports the communication with XML).

IV. ADVANTAGES OF THE PROPOSED PEDAGOGIC MODEL

The traditional method of medical students' evaluation excludes the consideration of individual learning characteristics, needs, preferences and rates from the process. Here, we proposed an adaptive environment for the evaluation process. We stressed the pedagogic model of the described adaptive environment and presented its content in detail. It can be used either for evaluation or self-evaluation purposes. Among the technical advantages of our proposal belong the following:

- Open model-driven architecture
- Reusable material, questions and tests by other applications
- Compliant with IMS QTI patterns and IMS LIP
- Easy expansible
- Applicable in various subjects.

From pedagogic view the learning process is upgrading as students can lead themselves towards attainment of specific goals and instructors can adjust the learning content to the students' learning rates. This can be achieved through a process of objective recording of students' cognitive strengths and weaknesses with reference to specific learning goals of every subject. Among the pedagogic benefits of both roles belong the following:

- The instructor sets the content and the form of evaluation questions.
- The instructor sets the date of exams while students can test themselves whenever they need.
- The instructor sets the grading rules permitting students to repeat or not an evaluation process.
- The instructor's evaluative role is facilitated because of an ontology form of connection between the concepts and learning goals. Thus, the instructor can produce various evaluative questions either for a test or an exam.
- The learning goals are connected with the learning preferences, interests, needs, skills etc.
- The learning profiles are updated after an exam and can be easily accessible by other instructors who teach the same students.
- Additional educational support can be provided if it is predicted so.
- Integrated feedback can be provided to the students as soon as completing their exams.

V. ADAPTIVE WEB-BASED INSTRUCTIONAL SYSTEMS

Adaptive Web-Based Instructional Systems (WBIS) are currently a highly active research field. They have started appearing as commercial applications. AWBIS are called upon to solve certain problems that originate from the traditional web-based instructional systems and are summarized as following:

- In instructional Systems that are not adaptive, the learners are lost during navigation through the hypermedia content and do not know where they have come from, where they are and where they can lead themselves.
- Cognitive overload. Too much effort is spent by the learner to comprehend the hypermedia structure, on the expense of the learning process. For example the learner tries too hard to comprehend the functions of the graphical user interface, instead of focusing on the learning content.
- They are either too restrictive, effecting in the loss of the user's flexibility and freedom, or too relaxed, resulting in chaotic structures.
- The variety of learning styles and learners' different performance causes it impractical and ineffective to treat all the learners in the same way. Instead, each learner should be treated in a personalized way, according to his/her performance, preferences and learning style.
- In cases where the learning process takes place without any teacher supervision (e.g. in distance learning), the learner must be fully supported and assisted by the instructional system.

- AWBIS are characterized by certain attributes and functions that solve the above problems. To begin with, AWBIS by adapting their content and links, leverage the complexity of the hypermedia structure, restraining the navigation and making it easier for the novice users to better orientate and avoid getting lost. On the other hand, they give expert users enough freedom and flexibility in their navigation, so that they won't feel constrained. Furthermore, they assist the novice users to focus on the content of the learning material instead of trying to comprehend the user interface. Finally they guide users with content and link adaptation and help them individually, according to their needs and preferences.

VI. DISCUSSION

The present study proposed a flexible and interoperable adaptive environment for evaluation purposes in Higher Education. Special emphasis was given to the pedagogic model while the other two models (the domain and the learner model) were described. As medical studies require the development of various skills and the establishment of a solid scientific knowledge base the instructors have special identified needs for facilitation of their role and objective attribution of their students' learning progress. On the one hand, the medical instructors need to know if their students' scientific knowledge level is low or high; what their cognitive and skilled strengths and weaknesses are; if they face specific difficulties that need additional support and which they are. On the other hand, the medical students will be the physicians of tomorrow and they have to be skilled and precise professionals. Their mistakes can be proved fatal. As wider knowledge and skills they have as more efficient they can be for the people's benefit.

The significance of the evaluation process in this domain of studies proves major and as a result the associated evaluators need to fully exploit the potentiality of adaptive environments. Despite the variety of proposed adaptive environments for (self) evaluation purposes the produced questions (evaluative items) are automatic and not defined by the instructor. Also, in most of them the instructor is just responsible for the main (or minor) parts of a test. In our proposal important responsibilities are transferred from the administrator to the instructor. The latter is authorized to create tests, specify grading and time rules, conduct exams and evaluate the students' results. At first glance it may seem as an instructor-centered process but at second glance it is deeply student-centered perspective as it turns the attention back to students. Their interests, cognitive strengths and weaknesses, needs and preferences are enhanced and taken into consideration when they are evaluated. As a result students proceed with their studies in an efficient way.

VII. CONCLUSION

The development of web-based learning environments that accommodate learners' individual differences is the real challenge for distance education taking into account the diversity of its audience as well as the issue that an instructional approach that benefits one category of learners may create obstacles for other categories. A critical issue in the development of such systems is the pedagogical background underlying the adaptation.

The characteristics of our proposal ensure that it can be easily used in Medical Education in various subjects as the issues of interoperability and adaptivity are covered. One of the open issues of our proposal is the connection, cooperation and compatibility with the other electronic systems of the Higher Education. Its expansion and integration in the educational process beyond the proposal stage becomes an important step for the complete provision of advanced electronic services for medical students.

REFERENCES

[1] Conejo, R., Guzman, E., Millan, E., Trella, M., Perez-de-la-Cruz, J.L., & Rios, A., SIETTE: A web-based tool for adaptive testing. International Journal of Artificial Intelligence in Education, 14, (2004), 1-33.

[2] De Bra, P., Aroyo, L., & Cristea, A., Adaptive web-based educational hypermedia. *Web Dynamics*, (2004), 387-410.

[3] Fisher, S., Course and exercise sequencing using metadata in adaptive hypermedia learning systems. ACM, *Journal of Educational Resources in Computing*, 1(1es), (2001).

[4] Guzman, E., & Conejo, R., A library for items construction in an adaptive evaluation system. Evidence Centred Design (ECD) approach to creating diagnostic e-assessments. San Sebastian, Spain, (2002), 78-86.

[5] Guzmán, E., Conejo, R., & García-Hervás, E., An Authoring Environment for Adaptive Testing. *Educational Technology & Society*, 8(3), (2005), 66-76.

[6] Hambleton, R.K., Swamination, H., & Rogers, H.J., Fundamentals of item response theory, (Newbury Park: Sage Publications, 1991).

[7] Leung, C.K., Chang, H.H., Hau, K.T., & Wen, Z., Computerized adaptive testing: A comparison of three content balancing methods. *Journal of Technology, Learning and Assessment*, 2(5), (2003). Available from http://www.jtla.org.

[8] Scott, N., & Stone, B., A Flexible web-Based tutorial system for engineering, maths and science subjects. *Global Journal of Engineering Education*, 2(1), (1998), 7-16.

[9] Wainer, H., Computerized adaptive testing: A primer (2nd Ed.), (Lawrence Erlbaum, Hillsdale, New Jersey, 2000).

[10] Brusilovsky, P., Methods and Techniques of Adaptive Hypermedia, *User Modeling and User-Adapted Interaction,* 6 (2/3), 87-129. 1996.

[11] Brusilovsky, P., Adaptive Hypermedia, *User Modeling and User-Adapted Interaction,* 11 (1/2), 111-127, 2001.

[12] Bull, S. & McCalla, G., Modelling cognitive style in a peer help network, *Instructional Science*, 30, 497–528, 2002.

[13] Federico, P.-A., Hypermedia environments and adaptive instruction, *Computers in Human Behavior,* 15, 653-692, 1999.

[14] Henze, N., Naceur, K., Nejdl, W. & Wolpers, M., Adaptive Hyperbooks for constructivist teaching, *Kunstliche Intelligenz,*26-31, 1999.

[15] Kay, J., Learner control, *User Modeling and User-Adapted Interaction,* 11(1/2), 111-127, 2001.

[16] Luckin, R. & Du Boulay, B., Ecolab: The Development and Evaluation of a Vygotskian Design Framework, *International Journal of Artificial Intelligence in Education*, 10, 198-220, 1999.

[17] Trapp, A., Hammond, N. & Bray, D., Internet and the support of psychology education, *Behavior Research Methods, Instruments, & Computers*, 28, 174 –176, 1996.

[18] White, B.Y., Shimoda, T.A. & Frederiksen, J.R., Enabling students to construct theories of collaborative inquiry and reflective learning: Computer support for metacognitive development, *International Journal of Artificial Intelligence in Education*, 10,151-182, 1999.

[19] Biggs J, What the Student Does: Teaching for Enhanced Learning,, Higher Education Research & Development, 18(1), 57-75, 1999.
[20] Bachman M. W, Lua M. J, Clay D. J et al, Comparing traditional lecture vs. computer based instruction for oral anatomy. J Dent Edu, 62, 587-591, 1998.